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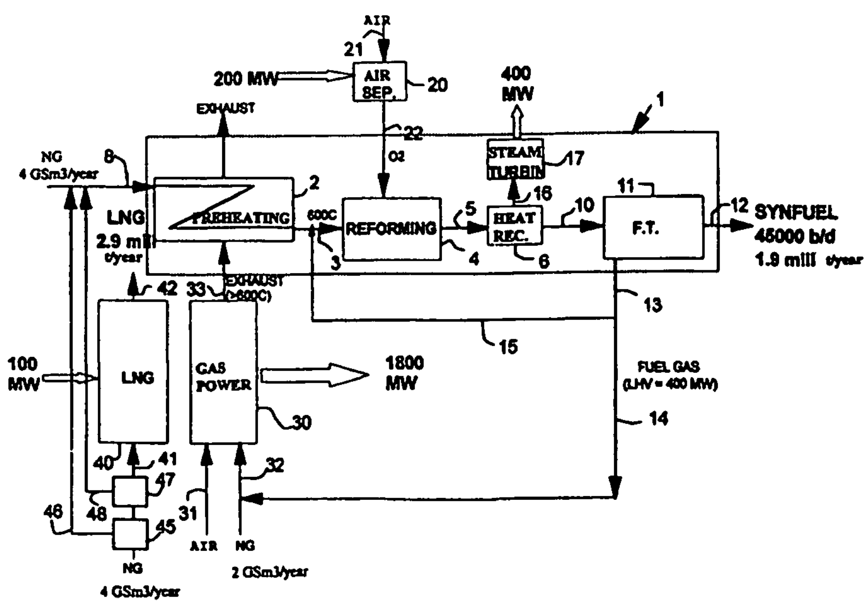

(57) Abstract

The present invention relates to a process and an integrated plant to be used in this process for the preparation of synthetic fuel (synfuel), liquefied natural gas, and production of electrical energy. A part of the energy produced is used for the operation of the energy requiring steps of the process, whereas the residual part is exported for other purposes.

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A PROCESS AND AN INTEGRATED PLANT FOR THE PRODUCTION OF SYNFUEL, LNG AND ELECTRICAL POWER

The present invention relates to a processing and converting a hydrocarbonous gas, such as e.g. natural gas in an integrated plant for the preparation of useful products, including chemical reaction products and mechanical or electrical power, as well as an integrated process plant for the accomplishment of such a process.

By the term «hydrocarbonous gas» in the present context and the appending claims is understood hydrocarbon compositions consisting of hydrocarbon components substantially existing in a gaseous form at standard pressure and temperature conditions.

Natural gas is an important part of numerous petrochemical reservoirs and can find utilisation as starting materials for further refined products in the form of pure hydrocarbons and in the form of oxidised derivatives thereof. Further, natural gas can be used for the production of power such as electrical power or mechanical power.

In many instances the natural gas reservoirs are situated at remote sites from the established natural gas markets where the utilisation thereof, as mentioned above, takes place. This is e.g. the case in Europe, where the petrochemical sources are situated at the sea bottom far away from the European continent.

As a consequence thereof it will not be economical to transport the gas through pipelines to the users, the pipeline systems being long and expensive to install and later also to maintain.

For this reason the options of converting natural gas to other transportable and useful products will be considered, such as e.g. liquefied gas (LNG= liquefied natural gas), synfuel (synthetically prepared engine fuels in liquid form) and electrical power. Depending on whether the further handling of the gas takes place at an offshore production platform or at the site of entering the ground, it is - provided that the further useful products are to be prepared at one and the same geographical site - economical to evaluate the integration benefits which may be

achieved by a suitable connection of the various kinds of plants for the abovementioned purposes.

Natural gas substantially consists of methane admixed with other gaseous hydrocarbons , CO_2 and gaseous sulphur compounds such as H_2S and lower mercaptanes.

When the methane is preheated to a temperature of the order 600°C and then is supplied with oxygen in a reforming step, oxygenated products of the methane are formed primarily in the form of CO and H_2. This gas composition is called «synthesis gas». Such a synthesis gas may alternatively be prepared by reducing carbon (usually in the form of coke) with water, and under pressure and at elevated temperatures, but also methane or higher hydrocarbons having a higher molecular weight according to the scheme:

$$C + H_2O \rightarrow CO + H_2$$

$$CH_4 + H_2O \rightarrow CO + 3H_2.$$

The synthesis gas is produced in an exothermal reaction, and power in the form of heat can be recovered from this step and optionally be converted to mechanical or electrical power.

The synthesis gas may then be reacted in a further step to methanol and dimethyl ether or in a Fischer-Tropsch synthesis to straight alkanes and/or alkenes of a higher molecular weight than the prevailing hydrocarbons of the natural gas.

$$nCO + (2n+1)H_2 \longrightarrow C_nH_{2n+2} + nH_2O$$

$$nCO + 2nH_2 \xrightarrow[\text{cobalt catalyst}]{} C_nH_{2n} + H_2O$$

The products of the reaction step of carbon monoxide and hydrogen gas is the product called «synfuel» (synthetic fuel) and being the intended product of the process.

Furthermore, non-reacted gas and side products may be recovered as a separate stream and may be recycled to the reforming step or used as fuel for the production of power.

The conversion of synthesis gas is e.g. disclosed in G.A. Mills, «Status and opportunities for conversion of synthesis gas to liquid fuels», Fuel, vol. 73(8) pp 1243-1279, (1994).

The Norwegian publication 179 169 discloses a process of converting natural gas to a normally liquid, carbonous compound such as methanol and/or dimethyl ether and/or liquid hydrocarbons of gasoline quality and/or olefins. The process avoids requirement of vapour reforming and/or adiabatic reforming of natural gas to synthesis gas using a substantially pure oxygen. The synthesis gas may be prepared at an operative pressure which is useful for converting the gas to methanol and/or dimethyl ether without recompression of the synthesis gas. The exhaust gas from the overhead has, subsequent to the conversion of the crude product methanol/DME and/or conversion to liquid hydro-carbons of gasoline quality, generally a BTU-capacity which is required for the use as fuel gas for the power supply being required for the operation of the required gas compression facilities used in the process. This renders the operation of the plant more economical and a process useful at remote sites. Particularly claim 4 of the publication for opposition states that air is introduced in the compressor unit of the gas turbine, the residual gas balance from the synfuel production including unreacted H_2, CO and methane, being introduced through the fuel entrance of the «expander- driver» unit of the gas turbine as a fuel for this part of the air from the outlet of compressed air from the gas turbine being lead to the entrance of a gas compressor driven by the gas turbine for compressing natural gas being introduced through the entrance to a gas compressor operated by a gas turbine and compressed to an enhanced end-pressure, the end-compressed air being heated to a higher temperature, the compressed natural gas being heated to a

high temperature, the compressed gases being used in an adiabatic reaction yielding a reformed gas stream having a temperature of 982-1371°C.

US Patent No. 4,594,140 discloses the preparation of synthesis gas from coke by the reaction with high pressure steam feed to a steam turbine generator, wherein electrical power is produced, whereas the exhaust gas is brought to a gasification plant and admixed with starting materials to be gasified and then passed to a shift reactor the products of which are again fed into the coke «liquefaction» plant. Steam is therein used as the source of energy, and the conversion to synthesis gas does not appear to be disclosed.

US patent No. 5.177.114 claims the same priority as the Norwegian publication No. 179169 and does not appear to differ substantially therefrom.

US patent No. 4.927.856 combines the production of electrical power, hydrogen gas production and methanol in an integrated system and discloses a corresponding process. The electricity is formed in turbines run by heated gas from a pressurised fuel source, and the electricity is then used in an electrolysis unit converting water, optionally condensed from the source gas, to hydrogen gas which is subsequently reacted with hydrocarbon oxides of the source gas under the formation of methanol.

US patent No. 5.245.110 discloses the preparation of an oxygen enriched gas composition in an apparatus comprising a gas turbine, an oxidation separation plant in a fluid connection with the turbine air compressor and means for maintaining an appropriate mass balance-tolerance between the turbine compressor unit and the turbine power production unit.

In US patent No. 5.284.878 methanol is produced by reacting a CO-rich synthesis gas in the presence of a powder methanol synthesis catalyst suspended in an inert aqueous phase reactor system. Unreacted CO-rich synthesis gas is recycled to the reactor. Preferably the process is integrated with a carbon gasification system for the production of electrical power in which one part of the unreacted synthesis gas is used as a fuel, and part of the methanol product is used as further fuel in periods of an increased demand.

The European Patent Application 0497425 A-1 discloses the preparation of organic compounds and production of power from heavy hydrocarbons by

gasification of the heavy hydrocarbons to a gaseous composition comprising hydrogen and carbonmonoxide, catalytic partial conversion of the gaseous composition to organic compounds by the use of a catalyst and production of electrical power from the non-converted gaseous composition by the use of a gas turbine / steam turbine cyclus.

US patent No. 4.296.350 discloses the production of mechanical and electrical power combined with synthesis or fuel gas in a partial oxidation process by integration combustion and steam turbines. The side product evaporated prior to condensed natural gas is brought through pipelines to the gas consumers. The conversion of the synthesis gas to synfuel is not disclosed.

US patent No. 4.359.871 discloses a process and an apparatus for the cooling of natural gas.

When gas recovered from petrochemical reservoirs at the sea bottom in arctic waters is brought ashore to a land based plant, in arctic regions, problems arise and conditions which are substantially distinguished from the conditions under which the abovementioned prior art aims to solve the problems.

The distance to the site of use is long and transport of gas through pipelines to these will require immense investments and pipelines which will be uneconomical.

Further, the sites of bringing ashore may be far away from suitable energy sources which are required in the further processing of the natural gas brought ashore.

These conditions result in particular problems which are therefore not found to be solved through the prior art technique.

A maximum integration of such a plant is desirable which must simultaneously produce products which are well suited for the transport in a liquid form to a site of use.

This problem may be solved by a process as disclosed in the introduction wherein

- unreacted natural gas or other hydrocarbonous gas is fed to a plant for converting the starting material via a hydrogen or carbon monoxide containing gas, particularly a synthesis gas, to a stream of conversion

products comprising a major part of the chemical reaction products, and an exhaust stream comprising a major part of unreacted amounts of carbon monoxide, hydrogen or synthesis gas, residual amounts of low molecular products, steam, carbondioxide and inert components,

- the starting material and optionally the exhaust gas stream from the gas conversion step are combined with an oxygen containing gas, preferably air, and then fed to a power plant for the production of mechanical or electrical power for operating the machinery of the integrated plant and for export, and for the production of a warm exhaust gas, and
- additionally natural gas is fed to a plant of recovery/separation or liquefaction of the single components of the natural gas, and that at least part of the required amount of power for this object is fed to the plant from the power plant or the conversion plant.

According to a preferred aspect of the process of the invention the conversion plant is fed the exhaust gas from gas power plant as an heat exchange medium to the preheating step for heating the natural gas starting material for the preparation of the carbonmonoxide containing gas.

A further preferred aspect of the process of the invention is the separation of air in an air separation plant for the preparation of an oxygen rich stream of gas which is reacted with the heated natural gas and optionally steam in the conversion plant for the preparation of a warm synthesis gas.

The required amount of energy for this aim is supplied to the air separation plant from the gas power plant or conversion plant.

The use of a plant for the production of LNG or NGL (Natural Gas Liquids) components are preferred as a plant for the recovery or liquefaction of the single components of the natural gas.

Further, a preferred aspect of the invention is that carbondioxide present in the Natural Gas being fed to the plant of recovery/separation or liquefaction of the single components of the natural gas starting material is separated from the gas stream in a separation unit and fed to the stream of other natural gas starting material to the conversion plant through a pipe.

A further preferred aspect of the process of the invention is the separation of carbon dioxide residing in the exhaust gas stream from the conversion plant or in the exhaust gas stream from the power plant from said gas stream and is fed to the stream of natural gas starting material to the conversion plant.

It is further preferred that cooling of the plant for recovery or liquefaction of the single components of the natural gas starting material at least partly is effected by heat exchange with cold fluid streams obtained in the air separation plant.

A further preferred aspect comprises that the natural gas starting material being fed to the conversion plant is heated in a preheating unit/furnace to a temperature of at least 500°C and reacted with an oxygenous gas and optionally steam in a reforming reactor for the partial oxidation and reforming of the starting material to a warm gas composition including hydrogen, carbon monoxide, carbon dioxide, oxygen or nitrogen, whereupon the resulting warm gas composition is passed through a heat recovery unit, in which a tempered gas composition having a temperature being lower than 350°C is obtained, and the tempered gas composition is reacted in one or more reactors to chemical reaction products and exhaust streams.

The last mentioned reaction may be a reaction to e.g. the oxidised products methanol and dimethyl ether or may be a Fischer-Tropsch reaction resulting in alkanes or alkenes, or the reaction may also involve a further reaction to more oxygenated products, e.g. a carbonylation of methanol to acetic acid.

As a consequence thereof, a preferred embodiment may be the presence of a synthesis gas composition in the reforming plant as a starting material for the preparation of Fischer-Tropsch products.

As a consequence of the abovementioned, a plant designed for the carbonylation and hydrocarbonylation of a suitable starting material can be used.

A further aspect may be that part of the exhaust stream from the last step of the conversion plant is recycled through a conduit to a previous step of the process, e.g. that it is admixed with the preheated natural gas and entering the reforming reactor with this. A preferred aspect is further that carbon dioxide which is recovered from the natural gas starting material which is fed to the plant for recovery/separation or liquefaction of single components of the natural gas

starting material, respectively carbondioxide as a part of the exhaust gas stream from the conversion plant is recycled to the inlet stream to the conversion plant, and that carbonmonoxide is recovered from the carbon monoxide containing gas being produced in the conversion plant and is used for the carbonylation of a suitable starting material.

It is further preferred that heat power being released by cooling of the warn gas composition being passed through the heat recovery unit is converted to further amounts of mechanical or electrical power.

Further it is preferred that compressed air for the preparation of an oxygen rich gas composition being used for the oxidation of the natural gas starting material of the conversion plant is taken from the outlet to an air compressor which is connected to a gas turbine of the power plant.

According to the invention it is further preferred that the air separation plant and the plant for recovery/separation or liquefaction of single components of the natural gas starting material use a common cooling circuit, or that cold product liquid streams, f. l. liquefied nitrogen, is heat exchanged against the gas or liquid streams entering said above mentioned plants.

Further, it is preferred that NGL-components (liquid components of the natural gas) are reduced in amount or removed from the natural gas, and the thus obtained NGL depleted natural gas is used as a starting material for the conversion to a carbon monoxide containing gas in the conversion plant, which conversion is performed by «gas heated reforming».

Further, the present invention relates to an integrated plant for processing and converting natural gas or other hydrocarbonous gas for the preparation of useful products including chemical reaction products and mechanical or electrical power, which integrated plant comprising:

* a plant for converting the starting material via a carbon monoxide containing gas, particularly a synthesis gas, to a stream of conversion products comprising a major part of the chemical conversion products and an exhaust stream, comprising a major part of unreacted amounts of carbon monoxide, hydrogen or synthesis gas, residual amounts of low molecular products, steam, carbon dioxide and inert components,

* a power plant for the production of mechanical or electrical power by reacting the starting material and optionally the exhaust gas stream from the gas conversion step with an oxygen containing gas, preferably air, for the operation of machinery of the integrated plant and for export, and for the production of a warm exhaust being used as heat exchange medium for heating the starting material for the production of the carbon monoxide containing gas of the conversion plant,

* a gas compression plant (40) for compressing, cooling or storage of natural gas as LNG (liquefied natural gas) having a CO_2 elimination plant (45) and a separation plant (47) for the separation of the heavier components (ethane, propane, butane) upstream.

In this integrated plant a connection is made between the gas power plant and the preheating means for the transport of exhaust gas from the first mentioned to the last mentioned, as well as heat exchange tubes in the last mentioned for an efficient transfer of heat from the exhaust gas to the natural gas which is to be preheated.

Further, it is preferred that the plant comprises an air separation plant for the preparation of an oxygen enriched gas stream for the feed to the reforming reactor for reforming the preheated natural gas from the preheating means. It is also preferred that the plant for recovery/separation or liquefaction of the single components is a plant for the production of LNG or NGL components.

In a further preferred aspect the plant comprises a separation device for the separation of gas for the plant for the recovery/separation or liquefaction of the single components of the natural gas material and gas to be led to preheating for reforming.

Further a heat exchange connection between this plant and the air separation plant is preferred.

It is preferred that the preheating means is designed for heating the natural gas to at least 500°C, that the reforming reactor is designed for partial oxidation and reforming of the natural gas to a warm gas composition including hydrogen, carbon monoxide, carbon dioxide, oxygen or nitrogen, and the heat recovering unit is designed to provide for a tempered gas composition having a temperature below 350°C.

A further preferred alternative embodiment of the conversion plant comprises a plant for carbonylation or hydrocarbonylation of natural gas.

It is also preferred that the gas power plant has a power production capacity substantially exceeding (e.g. more than 30 % of) the energy requirement of the plant for processing and converting natural gas into LNG.

In the following the invention is to be described with reference to the appending figure showing an integrated plant for the production of synfuel, LNG and gas power.

On the figure the fed amounts of natural gas and produced amounts of product and energy on a yearly basis is indicated.

MW = megawatt

t = ton.

A natural gas stream 8, which may include a supplement 46 from a plant for the partial liquefaction of natural gas is passed through a pipe to a preheating unit 2 having a heat supply by exhaust gas at a temperature above 600°C through a pipe 33 from a gas power plant 30 situated close by. The exhaust gas is passed in a unit 2 through a heat exchange plant for efficient transfer of heat to the natural gas to be heated. When required, a plant for further direct heating of the preheating unit may be provided. The exhaust gas is vented to the atmosphere after the delivery of heat to the preheating unit.

The preheated natural gas at a temperature of at least 600°C is then passed through conduits 3 to a reforming reactor 4.

This reforming reactor is simultaneously fed oxygen enriched gas from an air separator 20 which is again fed atmospheric air from the surroundings to an inlet 21, the feed of the oxygen enriched gas is indicated by 22. The reforming in the reforming reactor 4 is run under conditions which are closer defined in:

- I. Dybkjær, «Tubular reforming and autothermal reforming of natural gas - an overview of available processes», Fuel Processing Technology Vol. 42, pp 85-107 (1995).
- B.M. Tindall and M.A. Crews, «Alternative technologies to steam-methane reforming», (Hydrocarbon processing, 75, Nov 1995).

- Å. Solbakken, «Synthesis gas production», (Natural Gas Conversion pp 447-455, A. Holmen et al. (ed.). Elsevier Publ. 1991).

The synthesis gas including molecular hydrogen and carbon monoxide as the further desired reactants, but in admixture with oxygen, carbondioxide, nitrogen and other unreacted natural gas components, is passed through the pipe 5 to a heat recovery plant 6. About 400 MW may be recovered therefrom on a yearly basis. This heat can be used for the production of power as e.g. indicated by a steam turbine 17.

The cooled synthesis gas is then passed through a pipe 10 to a Fischer-Tropsch synthesis plant 11. The Fischer-Tropsch reaction of the Fischer-Tropsch synthesis plant will include a cobalt catalyst, e.g. a cobalt catalyst containing rhenium, which, in addition to cobalt, may include parts of rhenium and thorium oxide as disclosed in European patent application 0220343 A-1, or Fe-Co-spinels as e.g. disclosed in the European Patent Application No. 0216972 A-1. The catalyst may exist in a fixed bed as well as in a suspended form in the process.

Typical operation conditions for Fischer-Tropsch conversion are:

1. Total pressure of 5-80 bar, preferably 10-50 bar, particularly 20-40 bar,
2. Space velocity (the inverse of residence time): 100-20 000 vol. (SPT)/vol.(cat)*hours, preferably 300-10 000, particularly 500-5000.
3. Temperature 160-300°C, preferably 180-200°C, particularly 200-240°C.
4. Ratio H_2/CO (inlet) 1,0-3,0, preferably 1,5-2,5, particularly 1,7-2,1.

The synfuel produced is recovered as the product from the Fischer-Tropsch reaction through the outlet 12. This synfuel will be subject to a further refining process depending on the intended use, but this refining is not considered part of the present invention and is not disclosed herein.

Fuel gas is recovered from the Fischer-Tropsch synthesis through the outlet 13. Part of this gas stream may be recycled to a conduit 15 to the process, mixed with the preheated gas and together with this, passed to the reforming reactor.

The residual part is passed through a pipe 14 and mixed with natural gas fed through a conduit 32 to a gas power plant 30 which is simultaneously supplied with fuel air through a pipe 31. On an annual basis the gas power plant produces, by combustion of the mixture of natural gas and fuel gas from the Fischer-Tropsch reactor, about 1800 MW, at the same time supping exhaust gas as previously mentioned for the preheating of the natural gas to the reforming.

An integrated part of the plant is further a plant 45 providing for a compression and cooling of part of 4 giga standard m^3 per year by cooling and compression, which part is transported through pipes 41 to a storage plant 40 of liquid natural gas (liquefied natural gas = LNG). Prior to the condensation of this natural gas to LNG it is required to eliminate CO_2 from the gas to be condensed. This is performed in a CO_2 elimination plant 45.

If desired the heavier components (NGL's) of the natural gas (ethane, propane, butane) are first separated in a separation plant 47. This is a provision is LNG is to be produced in the process plant 40.

In this way e.g. a production of about 2.9 million tons per year LNG is obtained. The liquefaction requires about 100 MW per year and the cooling plant will preferably be integrated with a cooling plant for the air separation plant 20 providing for the oxygen enriched gas for the reforming. This plant requires about 200 MW per year.

The non-liquefied part of the gas from 45 is passed though a pipe 46 to the inlet of the preheating of the preheating plant 2 ad is thus led with an amount of 4 giga standard m^3 per year nature gas through 8 to the preheating.

A cryogenic process for the separation of air or preparation of nitrogen (and which concomitantly will result in an oxygen enriched stream of air) which can be used in the present air separation plant, is e.g. described in the Norwegian publication for opposition No. 177728.

A process for the preparation of intermediate distillates in Fischer-Tropsch synthesis with cobalt catalysts including parts of zirconium, titanium and chromium, followed by a hydrogenation conversion of the total synthesised products on a born noble-metal catalyst is disclosed in the European patent

application 0147873 A-1, and the conditions for the preparation of methanol from synthesis gas, is e.g. disclosed in the European patent application 0317035 A-2.

Particular benefits achieved by a plant according to the present invention of the kind disclosed herein, is that an integrated plant for the production of synfuel is obtained which, in addition to produce gas power in considerably economical amount, also results in exhaust gas which may be used for preheating the plant, the exhaust gas from the synfuel production constituting part of the fuel for the gas power plant to obtain a maximum utilisation of products and side-products from this plant.

Further, the integrated plant comprises a LNG plant partially producing liquid natural gas which may be transported, e.g. by tankers equipped for this purpose, to remove sites of consumption, and simultaneously part of the gas which can not be liquefied, to the synfuel process itself.

Such an integrated operation and such an integrated plant are, according to the applicant's knowledge, not previously described and constitute a valuable contribution to the field natural gas technology.

The inventive spirit is formulated in the appending claims. These are, however, not meant to limit the invention, all equivalents residing within the defined scope also having to be considered to constitute part of the inventive spirit.

What is claimed is:

1. A process for processing and converting a hydrocarbonous gas, particularly natural gas, as a starting material in an integrated plant for the preparation of useful products including chemical reaction products and mechanical and electrical power, wherein

* a starting material comprising a first part of the hydrocarbonous gas is fed to a plant (1) for converting the starting material via carbon monoxide containing gas, particularly a synthesis gas, to a stream of converted products comprising a major part of the chemical reaction products, and an exhaust gas stream comprising a major part of unreacted amounts of carbon monoxide, hydrogen or synthesis gas, residual amounts of low molecular products, steam, carbon dioxide and inert components,

a starting material comprising a second part of the hydrocarbonous gas and optionally the exhaust gas stream from the gas conversion step together with an oxygen containing gas, preferably air, is fed to a power station (30) for the production of mechanical or electrical power for the operation of machinery in the integrated plant and for export,

a starting material comprising a third part of the hydrocarbonous gas is fed to a plant (40) for the recovery/separation of liquefaction of the single components of the gaseous hydrocarbonous starting material and that at least part of the amount of power required for this purpose is fed to the plant (40) from the power plant (30) or a thermal power plant (17) connected to the conversion plant (1).

2. The process of claim 1, wherein a warm exhaust gas from the gas power plant (30) is fed as a heat exchange medium to the preheating step of heating the gaseous starting material for the preparation of the carbonmonoxide containing gas in the conversion plant.

3. The process of claim 1 or 2, wherein air is separated in an air separation plant (20) for the preparation of an oxygen rich gas stream which is reacted with

heated starting material and optionally steam in the conversion plant (1) for the preparation of a warm synthesis gas and the required amount of power for this purpose is fed to the plant (20) from the power plant (30) or the conversion plant (1).

4. The process of claim 2-3, wherein a plant for the preparation of LNG is used as a plant (40) for the recovery or liquefaction of single components of the natural gas.

5. The process of claim 2-4, wherein carbondioxide present in the hydrocarbonous starting material fed to the plant (40) for the recovery/separation or liquefaction of single components of the hydrocarbonous staring material is separated from the gas stream in a separation unit (45) and supplied to the stream of the starting material in the conversion plant (1) (by a pipe (46)).

6. The process of claim 1-5, wherein carbondioxide, which is present in the exhaust gas stream from the conversion plant (1), is separated from said gas stream and supplied to the stream of starting material in the conversion plant (1).

7. The process of the claims 2-5, wherein the cooling requirement of the plant (40) for the recovery or liquefaction of the single components of the gaseous starting material at least partly is covered by heat exchange with cold fluid streams obtained in the air separation plant (20).

8. The process of the claims 1-7, wherein the starting material which is fed to the conversion plant (1) is heated in a preheating unit/furnace (2) at a temperature of at least 500°C and reacted with an oxygen containing gas and possibly steam in a unit (4) for the partial oxidation and reforming of the starting material to a warm gas composition including hydrogen, carbon monoxide, carbon dioxide, oxygen or nitrogen, whereupon

- the resulting warm gas composition is passed through a heat recovering unit (6), whereby a tempered gas composition having a temperature being lower than 350°C, is obtained,
- the tempered gas composition is reacted in one or more reactors (11) to chemical reaction products and exhaust gas streams.

9. The process of the claims 1-8, wherein the conversion plant (1) manufactures a synthesis gas composition being used as a starting material for the preparation of Fischer-Tropsch products.

10. The process of the claims 1-8, wherein a plant which is designed for carbonylation or hydrocarbonylation of a suitable starting material, is used as conversion plant (1).

11. The process of the claims 1-8, wherein a plant which is designed for the manufacture of methanol or dimethyl ether or compositions thereof is used as conversion plant (1).

12. The process of the claims 1-11, wherein a part of the gas stream from the conversion plant (1) is recycled (via a pipe 15) to a previous step in the process.

13. The process of the claims 2-12, respectively 1-12, wherein carbon dioxide, which is either recovered from the hydrocarbonous starting material which is fed to the processing unit (40), or carbon dioxide being a part of the exhaust gas stream from the conversion plant (1) is recycled to the inlet stream of the conversion plant (1).

14. The process of the claims 2-13, wherein carbon monoxide recovered from the carbon monoxide containing gas which is manufactured in the conversion plant(1), and used for carbonylation or hydrocarbonylation of a suitable starting material.

15. The process of the claims 1-14, wherein heat power being released during cooling of the warm gas composition, which is passed through the heat recovery unit (6), is converted to further amounts of mechanical or electrical power.

16. The process of the claims 3-14, wherein compressed air for the preparation of an oxygen rich gas composition to be used for oxidation of the carbonous starting material in the conversion plant (1) is withdrawn from an outlet of an air compressor connected to a gas turbine of the power plant (30).

17. The process of the claims 3-16, wherein the air separation plant (20) and the plant (40) for the recovery/separation or liquefaction of the single components of the hydrocarboneous starting material utilises a common cooling circuit or the heat exchange of cold product fluid streams, e.g. liquid nitrogen, with gas or liquid streams entering the plants (20,40).

18. The process of the claims 3-16, wherein the contents of NGL components are reduced or eliminated from the natural gas, and the thus obtained NGL depleted natural gas is used as a starting material for the conversion to a carbon monoxide containing gas in the conversion plant (1), the conversion of the NGL depleted natural gas being effected by «Gas Heated Reforming».

19. An integrated plant for processing and converting a carbonous gas starting material, e.g. natural gas or another hydrocarbonous gas for the preparation of useful products including chemical reaction products and mechanical or electric power, wherein the integrated plant comprises

- a plant (1) for the processing and conversion of a hydrocarbonous gas, particularly a synthesis gas, to a stream of conversion products, comprising a major part of the chemical conversion products, and an exhaust gas stream comprising a major part of the unreacted amounts of carbon monoxide, hydrogen or synthesis gas, residual amounts of low molecular products, steam, carbon dioxide and inert components,

- a power plant (30) for the production of mechanical or electrical power by reacting the starting material and optionally the exhaust gas stream from the gas conversion step with an oxygen containing gas, preferably air, for the operation machinery in the integrated plant and for export,
- a gas processing plant (40) for compressing, cooling and storing natural gas as a LNG(liquefied natural gas) having a CO_2 elimination plant (45) and a separation plant (47) for the separation of the heavier components of the natural gas (ethane, propane, butane) upstream.

20. The plant of claim 19, wherein a connection (33) between the gas power plant (30) and the preheating plant (2) for the transport of exhaust gas from the first mentioned to the last mentioned for the conversion of heat from the exhaust gas to the natural gas is preheated.

21. The plant of claim 19, wherein in an air separation plant (20) for the preparation of an oxygen enriched gas stream as feed to the reforming means (4) for reforming the preheated natural gas from the preheating means (2).

22. The plant of claim 19, wherein the plant (40) is a plant for the preparation of LNG or NGL components.

23. The plant of the claims 19-22, comprising a separation means (45) for the separation of gas to the plant (40) and gas to be led to the preheating in the synfuel plant.

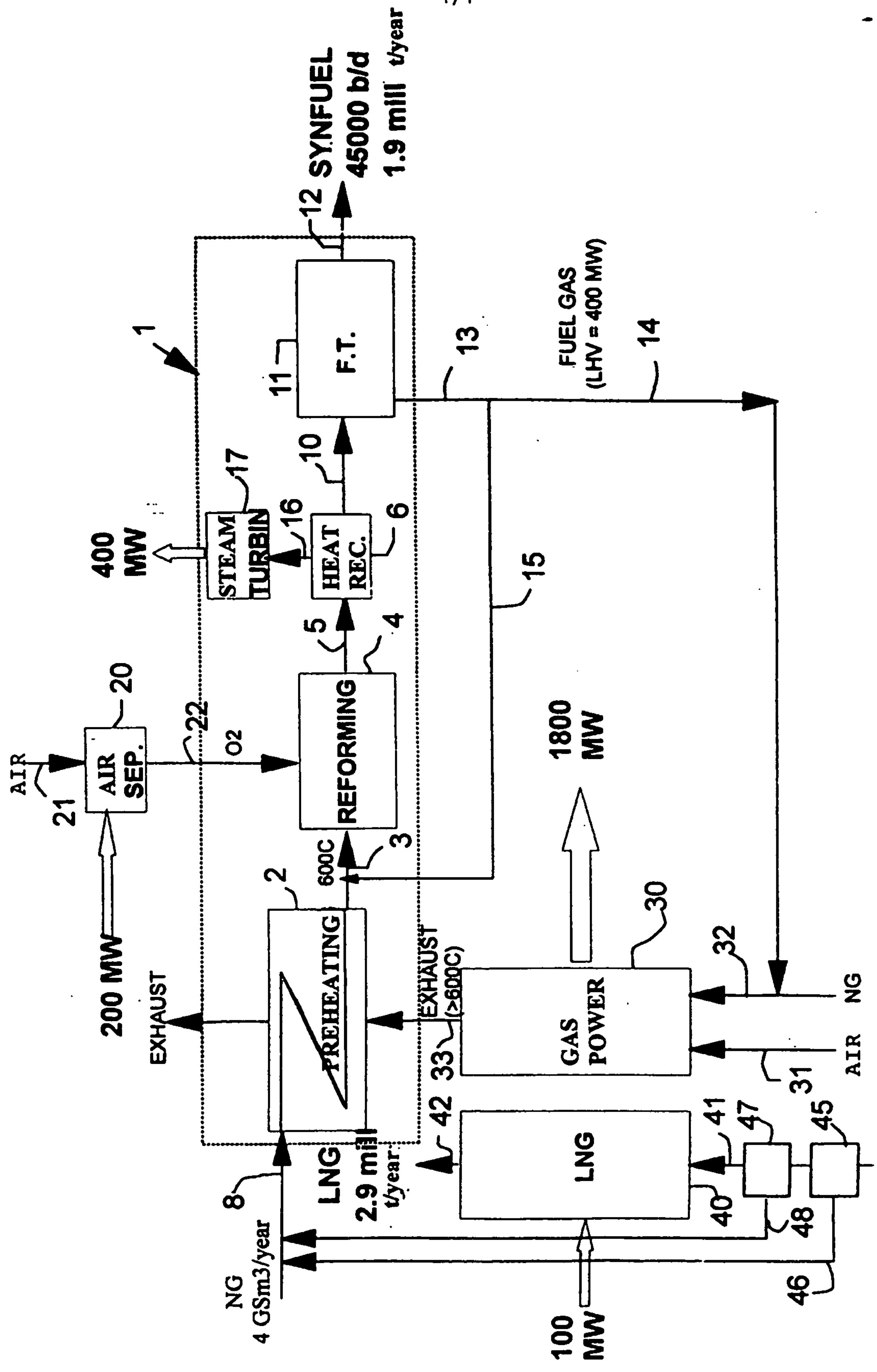
24. The plant of the claims 19-23, comprising a heat exchange connection from the air separation plant (20) to the plant (40) for the liquefaction of natural gas.

25. The plant of the claims 19-24, wherein the preheating means (2) is designed for heating natural gas to at least 500°C, the reforming means (4) being designed for partial oxidation and reforming of natural gas to a warm gas composition including hydrogen, carbon monoxide, carbon dioxide, oxygen or

nitrogen, and the heat recovery unit (6) is designed to provide a tempered gas composition having a temperature below 350°C.

26. The plant of the claims 19-25, wherein the conversion plant (1) is a plant for carbonylation or hydrocarbonylation of natural gas.

27. A plant for the coproduction of LNG and electrical power, comprising a plant for processing and converting natural gas into LNG and a gas power plant, which the gas power plant having a power production capacity substantially exceeding (e.g. by more than 30 % of) the power requirement of the plant for processing and converting natural gas into LNG.


SYNFUEL
45000 b/d
1.9 mill t/year
12
1
11
F.T.
13
FUEL GAS
(LHV = 400 MW)
14
10
17
STEAM
TURBIN
16
HEAT
REC.
6
400
MW
15
5
4
20
AIR
AIR
SEP.
21
22
O2
REFORMING
1800
MW
3
600C
2
PREHEATING
200 MW
EXHAUST
EXHAUST
(>600C)
30
GAS
POWER
32
NG
2 GSm3/year
33
AIR
31
LNG
2.9 mill
t/year
42
LNG
41
47
45
NG
4 GSm3/year
8
40
48
46
NG
4 GSm3/year
100
MW

FIGURE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 98/00024

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C10L 1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5177114 A (CHRISTIAAN P. VAN DIJK ET AL), 5 January 1993 (05.01.93), abstract, column 3, line 60 - line 68, column 8, line 26 - line 35 --	1-27
Y	64168 Gassteknologi, chapter 6: "Industriell utnyttelse av naturgass", Jan M. Overli, Institutt for termisk energi og vannkraft at NTNU, see in particular page 7 --	1-27
A	US 4594140 A (SHANG-I CHENG), 10 June 1986 (10.06.86), abstract --	1-27

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 1998	07-05-1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jack Hedlund Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Inte. .onal application No.
PCT/NO 98/00024

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4927856 A (GLENN R. ELION), 22 May 1990 (22.05.90), abstract --	1-27
A	US 5472986 A (CHRISTIAAN P. VAN DIJK), 5 December 1995 (05.12.95), abstract -- --------	1-27

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/04/98

Inter...ional application No.
PCT/NO 98/00024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5177114 A	05/01/93	AU 649445 B	26/05/94
		AU 7694291 A	30/10/91
		CA 2080339 A	12/10/91
		DE 69117287 D,T	14/08/96
		EP 0525027 A,B	03/02/93
		NO 179169 B,C	13/05/96
		WO 9115446 A	17/10/91
US 4594140 A	10/06/86	NONE	
US 4927856 A	22/05/90	NONE	
US 5472986 A	05/12/95	AU 4149296 A	31/05/96
		EP 0790969 A	27/08/97
		NO 972122 A	07/07/97
		WO 9614279 A	17/05/96